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A COMPARISON OF VARIOUS TECHNIQUES FOR SAMPLING GRANULAR MATERIALS

MATERIALS INFORMATION
ENGINEERING MATERIALS OFFICE

A Comparison of Various Techniques for Sampling Granular Materials

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INTRODUCTION

The Ministry of Transportation and Communications standard procedures for sampling granular materials are contained in Report EM-67 entitled "Guidelines for Acceptance Sampling and Testing of Granular Materials".

In these sampling procedures random numbers are used to pin-point one area from which a sample is obtained. Recently, concern has been expressed by some aggregate producers that these procedures should be modified to ensure a more representative sample by selecting a number of locations from which approximately equal portions of material are collected to make up the sample.

In order to determine if the suggested changes in the sampling method are warranted, a field study was initiated in September, 1984. In the study, gradation testing was carried out on samples obtained using three different sampling techniques. This report describes the sampling methods examined and discusses the comparison of the gradation test results.

SAMPLING AND TESTING PROGRAM

The different sampling techniques compared were as follows:

1) Single Increment Sampling Method.
   This is the technique now in use by the Ministry. In this method two random numbers are selected that are used to pin-point the sampling location. A sample bag is filled at this location by excavating with a modified tile spade as deep as possible without mixing with the underlying material.

2) Multiple Increment Sampling Method.
   This is the technique that was suggested. For this method random numbers were used to select four locations. At each location approximately 1/4 of the required sample was obtained by excavating with the modified tile spade.

3) Trench Sampling Method.
   This sampling method was used occasionally in the past by the Ministry. For this method, one random number is used to determine the location from which a trench is excavated across the full width, for the full depth, using a modified tile spade. All the excavated material from the trench is collected; however, generally this amounts to about three or four times the quantity required for a sample.

Each of the above techniques, with the possible exception of trench sampling, could be used regardless of whether road, stockpile or delivery sampling is adopted. It was felt that a comparative evaluation would suggest the same conclusion if all samples were obtained either from the road, from stockpiles or during delivery. Since the available resources for this project were limited, it was decided to compare the different methods on the basis of road samples only. This would enable the trench sampling technique to be included in the comparison as well.

The contract selected for the field work was Contract 83-71, since it required sufficiently large quantities of granular at a location convenient to our main testing facilities. The material sampled was Granular A, supplied from a commercial quarry.

The material was placed directly on the road by belly dump vehicles. Sixteen truck loads were selected for sampling. On every spread truck load, the three different methods were used to obtain three separate samples. Typical random sampling patterns and techniques are shown in Figure 1, 2 and 3.

The field work indicated that there were considerable differences in the times required for sampling by the three methods. It took the least amount of time to obtain a single increment sample (about 3 minutes per sample). The time for multiple increment sampling generally took 2 to 3 times longer depending on the length of the spread and the actual locations required for sampling. Trench sampling took the longest time (about 5 times that required for a single increment) since the large field sample had to be reduced to the appropriate size by splitting.

A total of 48 samples were labelled and transported to the Downsview laboratory for testing. The samples were tested using standard MTC procedures for gradation testing (MTC Laboratory Standard LS-602). The testing was performed by a single technician where possible to eliminate any possible chances of variation due to different operators.

The gradation test results for each sampling methods are given in Figure 4. Although these test results were not used for acceptance purposes, they were grouped into sets of four, and lot mean and range calculations were done for illustration purposes. These results are shown on Figure 4 also.

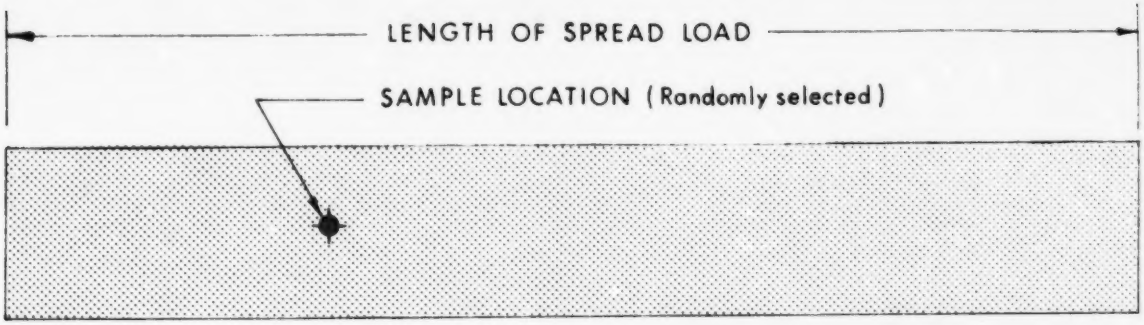


FIGURE 1: SINGLE INCREMENT ROAD SAMPLE

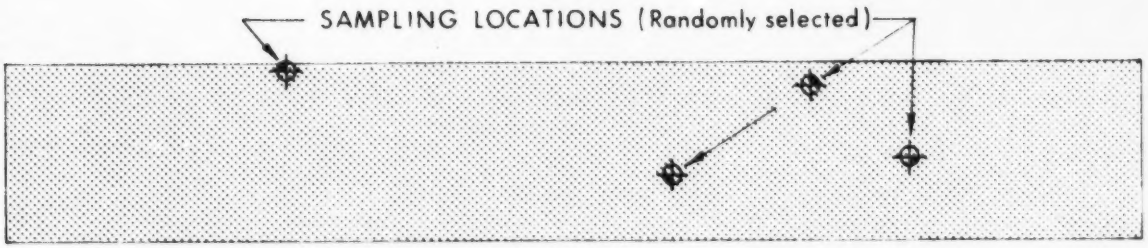


FIGURE 2: MULTIPLE INCREMENT ROAD SAMPLE

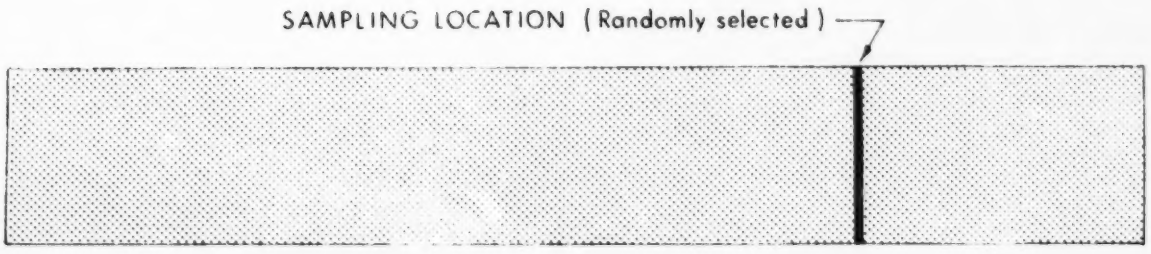


FIGURE 3: TRENCH SAMPLING

TRUCK SAMPLED	SAMPLING METHOD *	% PASSING MINISTRY DESIGNATED SIEVES						
		22.4 mm	19.0 mm	9.5 mm	4.75 mm	1.18 mm	300 um	75 um
1	1	100.0	95.1	64.6	46.2	21.1	8.7	4.3
	2	100.0	95.5	63.5	45.3	22.0	8.9	4.9
	3	100.0	95.6	65.2	46.2	20.8	8.5	4.4
2	1	100.0	95.7	64.8	47.5	24.6	11.3	6.2
	2	100.0	98.3	73.5	54.0	26.2	11.2	6.0
	3	100.0	96.3	69.6	50.8	23.3	10.8	5.9
3	1	100.0	97.3	73.9	54.4	26.7	12.0	6.6
	2	100.0	98.1	75.0	55.3	27.6	12.4	6.7
	3	100.0	98.1	72.3	53.1	26.1	12.0	6.4
4	1	100.0	98.8	79.4	59.0	29.1	13.2	7.2
	2	100.0	98.5	78.2	57.8	26.6	12.0	6.7
	3	100.0	98.0	72.9	52.5	24.3	11.0	6.1
Simulated Lot 1 Mean	1	100.0	96.7	70.7	51.8	25.4	11.3	6.1
	2	100.0	97.6	72.6	53.1	25.6	11.1	6.1
	3	100.0	97.0	70.0	50.7	23.6	10.6	5.7
Simulated Lot 1 Range	1	0.0	3.7	14.8	12.8	8.0	4.5	2.9
	2	0.0	3.0	14.7	12.5	5.6	3.5	1.8
	3	0.0	2.5	7.7	6.9	5.3	3.5	2.0

FIGURE 4a GRADATION TEST RESULTS

*SAMPLING METHODS:
1. FOR SINGLE INCREMENT SAMPLING
2. FOR MULTIPLE INCREMENT SAMPLING
3. FOR TRENCH SAMPLING

TRUCK SAMPLED	SAMPLING METHOD *	% PASSING MINISTRY DESIGNATED SIEVES						
		22.4 mm	19.0 mm	9.5 mm	4.75 mm	1.18 mm	300 um	75 um
5	1	100.0	99.0	78.7	56.5	27.8	13.1	7.0
	2	100.0	98.8	74.7	52.1	25.7	12.2	6.7
	3	100.0	98.3	73.6	51.1	25.7	12.2	6.5
6	1	100.0	97.5	67.0	47.7	22.9	9.8	5.1
	2	100.0	97.1	66.5	48.1	21.9	8.5	4.5
	3	100.0	98.4	70.5	51.9	24.7	10.1	5.3
7	1	100.0	97.9	69.4	48.8	21.9	9.3	5.1
	2	100.0	99.2	72.6	48.4	23.7	10.6	5.7
	3	100.0	97.6	70.1	45.4	21.4	9.6	5.4
8	1	100.0	97.0	71.1	50.8	25.5	10.9	5.6
	2	100.0	97.5	74.1	54.8	27.6	11.5	6.1
	3	100.0	96.1	66.4	46.6	22.0	9.6	5.0
Simulated Lot 2 Mean	1	100.0	97.9	71.6	51.0	24.5	10.8	5.7
	2	100.0	98.2	72.0	50.9	24.7	10.7	5.8
	3	100.0	97.6	70.2	48.8	23.5	10.4	5.6
Simulated Lot 2 Range	1	0.0	2.0	11.7	8.8	5.9	3.8	1.9
	2	0.0	2.1	8.2	6.7	5.7	3.7	2.2
	3	0.0	2.3	7.2	6.5	4.3	2.6	1.5

FIGURE 4b GRADATION TEST RESULTS (continued)

*SAMPLING METHODS:
1. FOR SINGLE INCREMENT SAMPLING
2. FOR MULTIPLE INCREMENT SAMPLING
3. FOR TRENCH SAMPLING

TRUCK SAMPLED	SAMPLING METHOD *	% PASSING MINISTRY DESIGNATED SIEVES						
		22.4 mm	19.0 mm	9.5 mm	4.75 mm	1.18 mm	300 um	75 um
9	1	100.0	98.9	79.4	55.3	28.2	13.5	7.6
	2	100.0	99.0	76.1	53.1	25.9	12.9	7.1
	3	100.0	98.8	78.6	53.9	27.6	13.8	7.6
10	1	100.0	98.3	70.9	51.2	22.6	9.5	5.1
	2	100.0	97.8	68.8	50.7	21.8	8.1	4.1
	3	100.0	96.2	66.4	46.6	20.7	8.3	4.3
11	1	100.0	98.1	76.5	52.6	25.1	11.5	6.2
	2	100.0	98.0	77.9	53.2	26.2	9.2	7.0
	3	100.0	98.9	77.3	53.7	27.2	13.6	7.3
12	1	100.0	99.0	74.5	51.9	26.6	12.4	6.6
	2	100.0	96.3	70.0	49.0	25.2	11.7	6.4
	3	100.0	96.9	73.6	51.9	22.8	10.5	6.0
Simulated Lot 3 Mean	1	100.0	98.6	75.3	52.8	25.6	11.7	6.4
	2	100.0	97.8	73.2	51.5	24.8	10.5	6.2
	3	100.0	97.7	74.0	51.5	24.6	11.6	6.3
Simulated Lot 3 Range	1	0.0	0.9	8.5	4.1	5.6	4.0	2.5
	2	0.0	2.7	9.1	4.2	4.4	4.8	3.0
	3	0.0	2.7	12.2	7.3	6.9	5.5	3.3

FIGURE 4c GRADATION TEST RESULTS (continued)

*SAMPLING METHODS:
1. FOR SINGLE INCREMENT SAMPLING
2. FOR MULTIPLE INCREMENT SAMPLING
3. FOR TRENCH SAMPLING

TRUCK SAMPLED	SAMPLING METHOD *	% PASSING MINISTRY DESIGNATED SIEVES						
		22.4 mm	19.0 mm	9.5 mm	4.75 mm	1.18 mm	300 um	75 um
13	1	100.0	98.1	72.6	52.7	25.8	11.6	6.3
	2	100.0	97.7	71.2	50.7	26.8	13.3	7.4
	3	100.0	98.4	75.7	52.6	25.2	12.0	6.6
14	1	100.0	99.3	78.4	52.8	28.0	12.2	6.3
	2	100.0	97.0	73.1	46.9	24.4	11.0	5.7
	3	100.0	98.5	75.4	49.8	24.2	11.5	6.1
15	1	100.0	97.7	71.6	49.6	23.5	10.1	5.5
	2	100.0	96.2	65.1	46.1	22.3	10.1	5.7
	3	100.0	97.2	55.8	45.6	22.2	9.7	5.5
16	1	100.0	98.4	72.7	48.7	21.9	9.3	5.1
	2	100.0	98.4	74.3	53.8	25.2	10.5	6.1
	3	100.0	97.8	71.5	50.7	22.3	9.7	5.4
Simulated Lot 4 Mean	1	100.0	98.4	73.8	51.0	24.8	10.8	5.8
	2	100.0	97.3	70.9	49.4	24.7	11.2	6.2
	3	100.0	98.0	72.1	49.7	23.5	10.7	5.9
Simulated Lot 4 Range	1	0.0	1.6	6.8	4.1	6.1	2.9	1.2
	2	0.0	2.2	9.2	7.7	4.5	3.2	1.7
	3	0.0	1.3	9.9	7.0	3.0	2.3	1.2

FIGURE 4d GRADATION TEST RESULTS (continued)

*SAMPLING METHODS:
1. FOR SINGLE INCREMENT SAMPLING
2. FOR MULTIPLE INCREMENT SAMPLING
3. FOR TRENCH SAMPLING

DISCUSSION

A comparison of the test results in Figure 4 indicates that there are slight differences in the test results for the different sampling methods. Slight differences also occur in the simulated lot range and lot mean values shown in Figure 4.

In order to gain further insights into the significance of these differences, statistical analyses were carried out to determine the mean and standard deviation of all test results for each sampling method. These results are summarized in the following table.

MINISTRY DESIGNATED SIEVES	% PASSING					
	MEAN			STANDARD DEVIATION		
	SAMPLING METHOD *			SAMPLING METHOD *		
	1	2	3	1	2	3
19.0 mm	97.9	97.7	97.6	1.2	1.1	1.1
9.5 mm	72.8	72.2	71.5	4.9	4.4	4.2
4.75 mm	51.6	51.2	50.2	3.5	3.6	3.0
1.18 mm	25.1	24.9	23.8	2.5	2.0	2.2
300 um	11.2	10.9	10.8	1.5	1.6	1.6
75 um	6.0	6.1	5.9	0.9	0.9	0.9

*SAMPLING METHODS:
1. FOR SINGLE INCREMENT SAMPLING
2. FOR MULTIPLE INCREMENT SAMPLING
3. FOR TRENCH SAMPLING

For illustration purposes the mean gradations for each sampling method have been plotted on the gradation chart, Figure 5. The trench samples indicated a slightly coarser material than the other sampling methods. However, essentially there is no difference between the mean gradation test results of the three sampling methods.

The standard deviation of the sixteen test results is an indication of the variation between test results for a given sampling method. The greater the standard deviation, the greater the variation between test results. Lot ranges are also indicators of variations in test results. In general, the standard deviations were slightly higher for the single

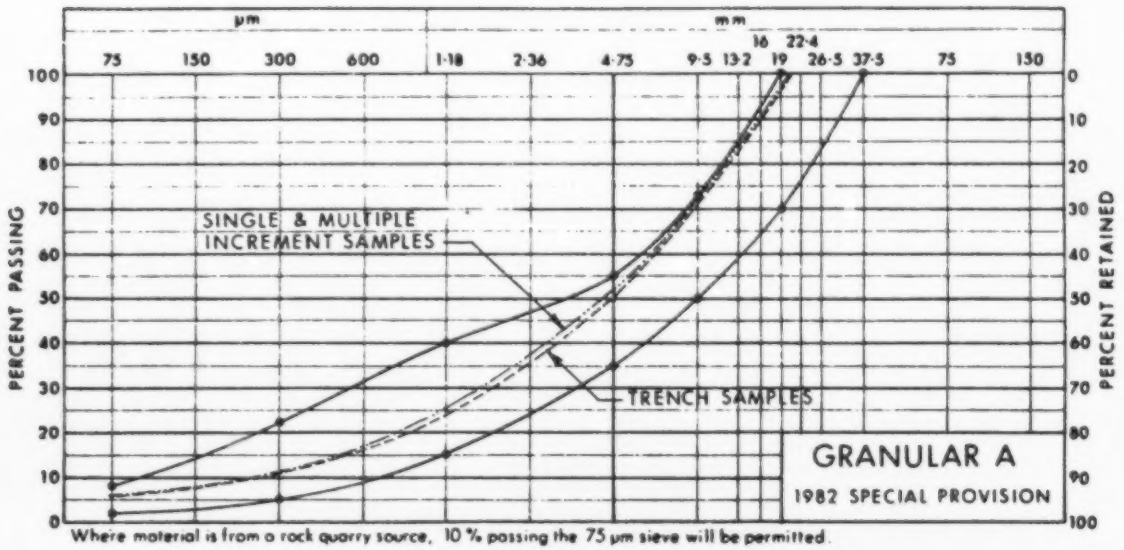
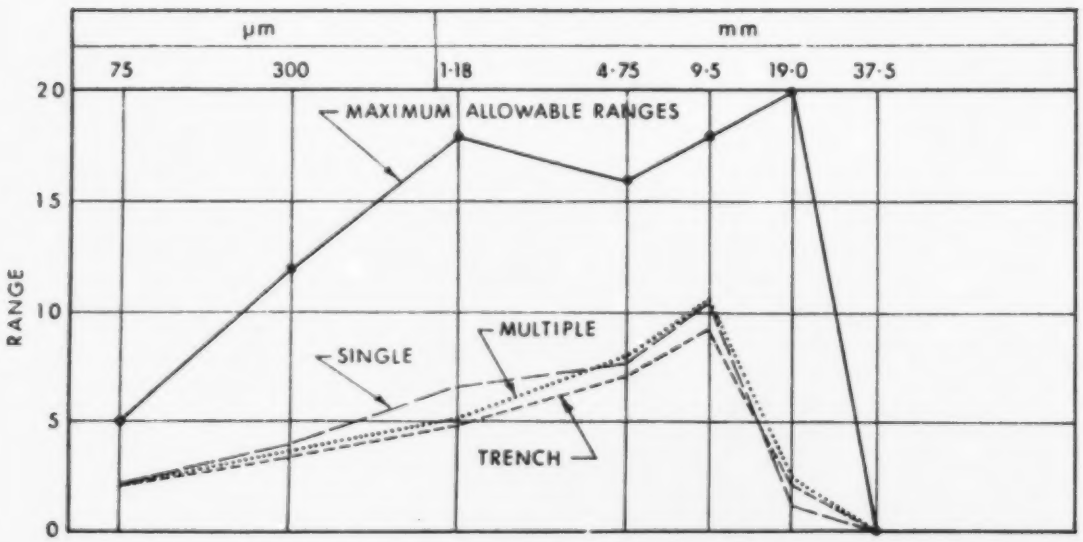


FIGURE 5



AVERAGE RANGES OF THE THREE SAMPLING METHODS

FIGURE 6

increment sampling method. Lot ranges for the single and multiple increment sampling were about the same while lot ranges for trench sampling were somewhat less for the coarse aggregates sieves (See Figure 6). However, essentially there is no difference in the standard deviations and lot ranges.

To further study the effect on gradation test results by the three sampling methods, a statistical technique known as analysis of variance, or ANOVA, was carried out. In this form of analysis the individual test results are compared statistically to determine if the differences in test results for each sampling method can be attributed to material variations alone or to a combination of material variations and sampling variations. It is beyond the scope of this report to explain in detail the ANOVA analysis. Interested readers can refer to any statistical text book for more details (1). For documentation purposes the ANOVA tables have been included in Appendix 1. This analysis indicated that the slight differences in the test results are due to material variations only. In other words, regardless of the sampling method used we would expect the same test results, and the same lot mean and lot range values.

(1) RICHMERS, A.D. and H.N. TODD; 1967, Statistics: **An Introduction,** McGraw - Hill Book Company.

CONCLUSIONS AND RECOMMENDATIONS

This study has examined the effect of three different sampling methods on the gradation test results of a Granular A material. The three sampling methods evaluated were single increment sampling; multiple increment sampling; and trench sampling.

The conclusions of the study are as follows:

1. Analysis of the test results indicated that the three sampling methods investigated had no effect on the test results.

2. Field trials indicated that the single increment sampling method took the least amount of time (about 3 minutes per sample). The time required for the multiple increment sample varies depending on the random locations and length of spread. Generally, multiple increment sampling took 2 to 3 times longer than single increment sampling. Trench sampling took about 5 times longer than a single increment sample.

In view of the above and in consideration of the staff's familiarity with the existing methods, it is recommended that the Ministry continue with the existing sampling practice of single increment sampling.

ACKNOWLEDGEMENTS

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Thanks are also due to Ms N. DeRocchis for her thoroughness in typing this report.

Appendix

Appendix - Analysis of Variance (ANOVA)

SAMPLING COMPARISON - 19.0 mm SIEVE

SOURCE	SUM OF SQUARES	V	MEAN SQUARE	F RATIO	F CRITICAL
VARIATION	1.03125	2	.515625	2.34343	19.471
ERROR	54.375	45	1.20833		
TOTAL	55.4063	47			

SAMPLING COMPARISON - 9.5 mm SIEVE

SOURCE	SUM OF SQUARES	V	MEAN SQUARE	F RATIO	F CRITICAL
VARIATION	12.7656	2	6.38281	3.12972	19.471
ERROR	898.938	45	19.9764		
TOTAL	911.703	47			

SAMPLING COMPARISON - 4.75 mm SIEVE

SOURCE	SUM OF SQUARES	V	MEAN SQUARE	F RATIO	F CRITICAL
VARIATION	18.2344	2	9.11719	1.27604	19.471
ERROR	523.523	45	11.6339		
TOTAL	541.758	47			

SAMPLING COMPARISON - 1.18 mm SIEVE

SOURCE	SUM OF SQUARES	V	MEAN SQUARE	F RATIO	F CRITICAL
VARIATION	16.3457	2	8.17285	1.59486	3.231
ERROR	230.602	45	5.12448		
TOTAL	246.947	47			

SAMPLING COMPARISON - 300 um SIEVE

SOURCE	SUM OF SQUARES	V	MEAN SQUARE	F RATIO	F CRITICAL
VARIATION	1.04297	2	.521484	4.80837	19.471
ERROR	112.837	45	2.50749		
TOTAL	113.88	47			

SAMPLING COMPARISON - 75 um SIEVE

SOURCE	SUM OF SQUARES	V	MEAN SQUARE	F RATIO	F CRITICAL
VARIATION	.29248	2	.14624	5.81912	19.471
ERROR	38.2946	45	.85099		
TOTAL	38.587	47			

Where: VARIATION - Variation due to Sampling method
ERROR - Variation due to Testing and actual material variation
V - Degree's of Freedom